

XXXIV. *Description and Use of a portable Wind Gage.*
By Dr. James Lind, Physician, at Edinburgh.

Redde, May 11, 1775. **T**HIS simple instrument consists of two glass tubes *AB*, *CD*, of five or six inches in length (TAB. x. fig. 1.). Their bores, which are so much the better always for being equal, are each about $\frac{4}{10}$ ths of an inch in diameter. They are connected together, like a siphon, by a small bent glass tube *ab*, the bore of which is $\frac{1}{10}$ th of an inch in diameter. On the upper end of the leg *AB* there is a tube of latten brass, which is kneed or bent perpendicularly outwards, and has its mouth open towards *F*. On the other leg *CD* is a cover, with a round hole *G* in the upper part of it, $\frac{2}{10}$ ths of an inch in diameter. This cover and the kneed tube are connected together by a slip of brass *cd*, which not only gives strength to the whole instrument, but also serves to hold the scale *HI*. The kneed tube and cover are fixed on with hard cement or sealing wax. To the same tube is soldered a piece of brass *e*, with a round hole in it, to receive the steel spindle *KL*, and at *f* there is just such another piece of brass soldered to the brass hoop *gb*, which surrounds both legs of the instrument. There is a small shoulder on the spindle at *f*, upon which the instrument

B b b 2

rests,

rests, and a small nut at *i*, to prevent it from being blown off the spindle by the wind. The whole instrument is easily turned round upon the spindle by the wind, so as always to present the mouth of the kneed tube towards it. The end of the spindle has a screw on it; by which it may be screwed into the top of a post, or a stand made on purpose. It also has a hole at *L*, to admit a small lever for screwing it into wood with more readiness and facility. A thin plate of brass *k* is soldered to the kneed tube, about half an inch above the round hole *G*, so as to prevent rain from falling into it. There is likewise a crooked tube *AB* (fig. 2.), to be put on occasionally upon the mouth of the kneed tube *F*, in order to prevent rain from being blown into the mouth of the wind-gage, when it is left out all night, or exposed in the time of rain. The force or *momentum* of the wind may be ascertained by the assistance of this instrument, by filling the tubes half-full of water, and pushing the scale a little up or down, till the *o* of the scale, when the instrument is held up perpendicularly, be on a line with the surface of the water, in both legs of the wind-gage. The instrument being thus adjusted, hold it up perpendicularly, and turning the mouth of the kneed tube towards the wind, observe how much the water is depressed by it in the one leg, and how much it is raised in the other. The sum of the two is the height of a column of water which the wind is capable of sustaining at that time; and every body that is opposed to that wind, will be pressed upon by a force equal to the weight of a column

lumn of water, having its base equal to the surface that is opposed, and its height equal to the altitude of the column of water sustained by the wind in the wind-gage. Hence the force of the wind upon any body where the surface opposed to it is known, may be easily found; and a ready comparison may be made betwixt the strength of one gale of wind and that of another, by knowing the heights of the columns of water, which the different winds were capable of sustaining. The heights of the columns in each leg will be equal, provided the legs are of equal bores; but unequal, if their bores are unequal. For suppose the legs equal, and the column of water the wind sustains to be three inches, the water in the leg, which the wind blows into, will be depressed one inch and a half below 0, and raised just as much above it in the other leg. But if the bore of the leg which the wind blows into, be double that of the other, the water in that leg will be depressed only one inch, whilst it is raised twice as much, or two inches, in the other; and *vice versâ*, if the same wind blow into the smaller leg it will depress the water in it two inches, whilst it raises it only one inch in the other. The force of the wind may be likewise measured with this instrument, by filling it until the water runs out at the hole *G*. For if we then hold it up to the wind as before, a quantity of water will be blown out; and, if both legs of the instrument are of the same bore, the height of the column sustained, will be equal to double the column of water in either leg, or the sum of what is wanting in both legs

But

But if the legs are of unequal bores, neither of these will give the true height of the column of water which the wind sustained. But the true height may be obtained by the following *formulae*.

Suppose that after a gale of wind, which had blown the water in one of the tubes from A to B (fig. 3.), forcing it at the same time through the other tube out at E, the surface of the water should be found standing at some level DG, and it were required to know what was the height of the column EF or AB, which the wind sustained. In order to obtain which, it is only necessary to find the height of the columns DB or GF, which are constantly equal to each other: for either of these added to one of the equal columns AD, EG, will give the true height of the column of water which the wind sustained.

C A S E I.

Let the diameters AC, EH, of the tubes be respectively represented by c, d ; and let $a=AD$ or EG , and $x=DB$ or GF . Then it is evident, that the column DB is to the column EG as c^2x to d^2a . But these columns are equal. Therefore, $c^2x=d^2a$; and consequently, $x=\frac{d^2a}{c^2}$.

E X A M P L E.

If the diameters AC, EH, be respectively 10 and 1, and AD or $EG=3,96$ inches, x will be $=,0396$ of an inch. For $d^2a=1 \times 3,96=3,96$, which divided by $c^2=100$, gives $x=,0396$.

C A S E

C A S E II.

But if at any instant of time, whilst the wind was blowing, it was observed, that when the water stood at E , the top of the tube out of which it is forced, it was depressed in the other tube to some given level BF , the altitude at which it would have stood in each, had it immediately subsided, may be found in the following manner:

Let $b=AB$ or EF . Then it is evident, that the column DB is equal to the difference of the columns EF , GF . But the difference of these columns is as d^2b-d^2x . Therefore

$$c^2x=d^2b-d^2x; \text{ and consequently, } x=\frac{d^2b}{c^2+d^2}.$$

For the cases when the wind blows in at the narrow leg of the instrument.

Let $AB=EF=b$, EG or $AD=a$, $GF=DB=x$, and the diameters EH , CA , respectively $=d$, c , as before. Then it is evident, that the column AD is to the column GF as ac^2 to d^2x . But these columns are equal. Therefore, $d^2x=ac^2$; and consequently, $x=\frac{ac^2}{d^2}$. This answers to

CASE I.

It is also evident, that the column AD is equal to the difference of the columns AB , DB . But the difference of these columns is as bc^2-c^2x . Therefore, $d^2x=bc^2-c^2x$.

Whence we get $x=\frac{bc^2}{d^2+c^2}$. This corresponds to CASE II.

As there is always a calculation to be made for every

experiment when the legs of the instrument are of unequal bores, I would recommend it to the makers of these instruments, to make use of tubes that are equal, or at least nearly so, that the error may become next to nothing, it being a thing very easy to be done. In this manner we can readily determine the greatest force, which the wind has blown with, during the time the instrument has been exposed to its action. But as it may be safely left alone, by screwing its spindle into the proper stand, or into the top of a post, and as the wind never fails to turn the mouth of it towards itself, it is not necessary for the observer to continue always by it; for it may be allowed to stand all night, exposed to the wind, without any inconvenience, though it should even happen to rain very heavily. However, recourse can only be had to this method of using the instrument on shore: for at sea it must always be held up in a perpendicular position in the hand, whether it be used when only half full of water, or when quite full; which last will be frequently found to be the only practicable method of ascertaining the force of the wind during the night, when it blows so hard that it is impossible to keep any lights on deck. A person filling the wind-gage, in a calm place, with water, in order to determine the force of the wind, in the way which I have been just now describing, will be apt to imagine, that it cannot give the measurement correct; for he will find such a repulsion to arise from the edges of the hole *G*, as to sustain a column of water in the knee'd or bent tube, perhaps half an inch above the level;

level: but by either blowing across the round hole, or moving his finger over it, he will soon bring the water in the kneed tube to stand at the same level with it, by taking off gradually the convex fuface of the water, which projects out at the hole in the form of a drop or *spherule*. And this effect the wind very soon produces itself. There ought always to be a cover on the top of the tube out of which the water is expelled by the wind; but it should be made very thin. For if there be no such cover, and the mouth of the kneed tube be stopped, after the instrument is quite full of water, in order to prevent the wind from having any influence in raising it, you will find, upon exposing it to a strong gale, that in a very short time it will blow out perhaps half an inch of water. Whence it appears, that a very considerable error would arise from using the wind-gage in this state. But in all the experiments which I have made with this instrument, whilst it had the cover and the round hole of $\frac{2}{10}$ ths of an inch in diameter in the middle of it, I have not been able to discover any error. The use of the small tube of communication *ab* (fig. 1.) is to check the undulation of the water, so that the height of it may be read off from the scale with ease and certainty. But it is particularly designed, to prevent the water from being thrown up to a much greater or less altitude, than the true height of the column, which the wind is able at that time to sustain, from its receiving a sudden impulse, whilst it is vibrating either in its ascent or descent. For water in the legs of a siphon is capable of being put

into a vibrating motion like a pendulum^(a); and therefore, if acted upon when in the ascent, the height which it ascends to will come out greater than the truth; and less, if acted on in the descent.

The height of the column of water sustained in the wind-gage being given, the force of the wind upon a foot square is easily had by the following table, and consequently on any known surface.

T A B L E I.

| Height of the water in the wind-gage. | Force of the wind on the foot square in avoirdupois pounds. | Common designation of such a wind. |
|---------------------------------------|---|------------------------------------|
| 12 inches | 62,5 | |
| 11 | 57,293 | |
| 10 | 52,083 | |
| 9 | 46,875 | |
| 8 | 41,667 | most violent hurricane. |
| 7 | 36,548 | very great ditto. |
| 6 | 31,75 | great hurricane. |
| 5 | 26,041 | hurricane. |
| 4 | 20,833 | very great storm. |
| 3 | 15,625 | great ditto. |
| 2 | 10,416 | storm. |
| 1 | 5,208 | very high wind. |
| 0 $\frac{1}{2}$ | 2,604 | high wind. |
| 0 $\frac{1}{10}$ | ,521 | brisk gale. |
| 0 $\frac{1}{20}$ | ,260 | fresh breeze. |
| 0 $\frac{1}{40}$ | ,130 | pleasant wind. |
| | | a gentle wind. |

(a) NEWTONI Princip. Mathemat. lib. II. prop. XLIV. theor. XXXV.

E X A M P L E.

If it were required to know the force of the wind, when the column of water sustained was equal to $4\frac{6}{15}$ inches. Then, by TAB. I.

| | Pounds. |
|-----------------------------|---|
| 4 inches = | 20,833 |
| 0,5 or $\frac{1}{2}$ inch = | 2,604 |
| 0,1 = | 0,521 |
| Sum <u>4,6</u> = | <u>23,958</u> = force on every square foot. |

Any change that can happen in the specific gravity of the water from heat or cold, will make no sensible alteration on experiments made with this instrument.

A cubic foot of water is generally supposed to weigh 1000 Avoirdupois ounces; and from some experiments made by Mr. MUSSCHENBROEK it would appear, that betwixt freezing and boiling, or in 180° on FAHRENHEIT's scale, it increases only $\frac{1}{85} = ,0117$ of its whole bulk, or volume^(b). I cannot, however, find any author that mentions at what precise degree of heat a cubic foot of water was weighed. Mr. FAHRENHEIT indeed made several of his curious experiments on the specific gravities of bodies when the water raised his thermometer to 48° ^(c). Now if we suppose the greatest heat of the water which

(b) MUSSCHEN. Introd. ad' Philos. Natur. tom. II. p. 625.

(c) Philosophical Transactions, N° 383.

we make use of in the wind-gage to be 90° , which exceeds 48° by 42, the greatest change produced will be only ,0027 or $\frac{27}{10000}$ parts of the whole. So that if the altitude of the column of water sustained by the wind were even to be five inches, the part of this effect, arising from the diminution of the specific gravity of the water, occasioned by the greatest heat, will only amount to 0,0135, or $\frac{135}{10000}$ parts of an inch, a change which cannot be measured by the instrument. It may be sometimes necessary to employ other fluids besides water, particularly if the degree of cold be below freezing: for then we must use a fluid that will not freeze in the degree of cold in which we expose the instrument, otherwise the wind can have no influence on it, and the liquor freezing in the tube will break it. I shall, therefore, mention a few liquors in the following table that will answer the purpose, as also subjoin a general method of reducing them all to one common measure. But of all the fluids I am acquainted with, when the effects of frost are to be feared, I know none better adapted to our purpose than a saturated solution of sea-salt; since it does not freeze till the thermometer falls to 0 degrees, and is a fluid constantly of the same specific gravity. Spirit of wine, independent of its being more variable in respect of specific gravity by the influence of heat and cold, is also more or less so, as it is more or less rectified. And although the true specific gravity were known at the beginning of the operation, it would even change during the time of using it, by imbibing moisture from the air.

Let w represent the weight of a column of water, having its altitude measured by one of the divisions on the scale, and its base to any given surface whatever; and let n denote in general the number of these divisions which measures the whole length of the column of the water which the wind sustains. Then nw will represent always its weight, and will serve as a common-multiplier for the specific gravities of all other liquors.

T A B L E II.

| Names of liquors. | Specific gravities. | Common multiplier. | Weight measuring the forces of the wind. |
|-------------------|---------------------|--------------------|--|
| Water, | 1,000 | | nw |
| Sat sol. of salt, | 1,244 | | $1,244 \times nw$ |
| Urine, | 1,030 | | $1,030 \times nw$ |
| Ditto, | 1,016 | | $1,016 \times nw$ |
| Alkohol, | 0,825 | | $0,825 \times nw$ |
| Proof spirits, | 0,927 | | $0,927 \times nw$ |
| etc. &c. | | | &c. &c. |

E X A M P L E.

Let w represent the weight of a column of water $\frac{1}{20}$ th of an inch high, standing on a square foot; and let $n=80=4$ inches. Then (by TAB. I.) nw is equal to $20,833$ Avoirdupois pounds. Therefore $1,244 \times 20,833$ = weight of a saturated solution of sea salt of the same altitude, and $\frac{4}{1,244}$ = the altitude of a column of a saturated solution of the same, weighing $20,833$ pounds Avoirdupois.

dupois. w may represent a square yard, the surface of a sail, &c.

If the velocity and density of the wind in any particular case were accurately determined, this instrument, which gives its force or *momentum*, would enable us to ascertain the velocity in every other case, the density being known. For it appears from experiments, made by Mr. JAMES FERGUSON, F. R. S. on the whirling-table, that its force is as the square of its velocity. But as the density, which is one of the *data* requisite for determining the velocity by this instrument, was not taken into consideration in these experiments, all that we can do at present is to suggest the idea.

It may not, perhaps, be improper to take notice, that evaporation will have some effect in diminishing the altitude of the column of water; though its influence, for the most part, will be very inconsiderable. The more frequently, therefore, the instrument is examined, it will be so much the better. If it be exposed to the action of the wind, whilst it happens to snow, it will be necessary to look at it frequently, least the snow should choak up the mouth of the wind-gage.

Extract of a letter from Dr. LIND to Col. ROY. Dated Edinburgh, May 26, 1775.

The wind-gage ought to be somewhat longer than that I lately sent Sir JOHN PRINGLE. For we had a gale here on the 9th current, which supported a column of water
of

of $6\frac{7}{10}$ inches, whereas that I sent was not so long. The force of this gale on a square foot was equal to 34,921 pounds Avoirdupois, and it has done great damage to our gardens. West India hurricanes would require gages of a still greater length to measure them.

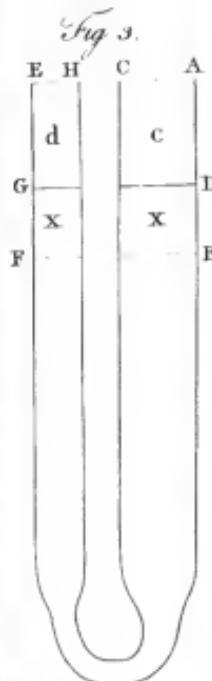
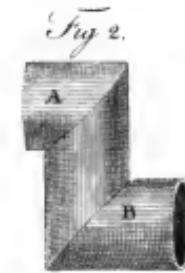
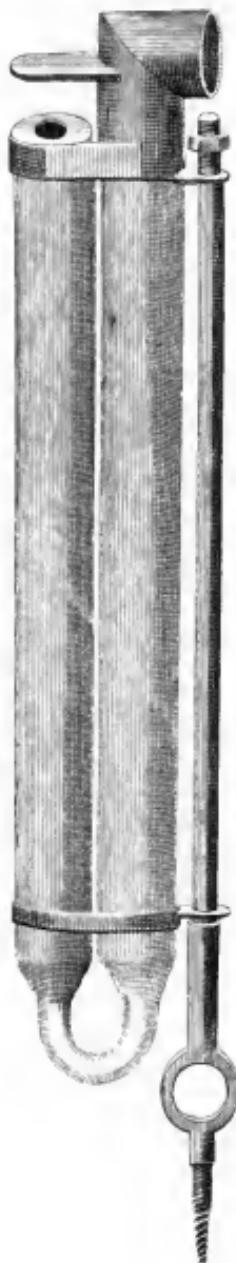


Fig. 1.